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Civil Engineering

ROOF SYSTEMS MANAGEMENT

COMPLIANCE WITH THIS PUBLICATION IS MANDATORY

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(Mr Julian L. Ius)
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(Col Donald J. Thomas)
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This instruction implements AFR 32-10, *Installations and Facilities*, and provides guidance for establishing and maintaining a roof management program. It also specifies use of the *Maintenance Membrane Roofing Systems* manual, published by The Roofing Industry Educational Institute. Send recommendations for changes or improvements to this publication on AF Form 847, **Recommendation for Change of Publication**, through the major commands (MAJCOM) and HQ AFCEA/ENC, 139 Barnes Dr., Tyndall AFB FL 32403-5319 to HQ USAF/CEO, 1260 Air Force Pentagon, Washington DC 20330-1260. See attachment 1 for a list of references.

SUMMARY OF CHANGES

This is the initial publication of AFI 32-1051, which substantially revises AFR 91-36.

Section A—Definitions and Responsibilities

1. Program Objective. The objective of a roof maintenance program is to reduce the life cycle cost of Air Force roofs. Roof management involves periodic inspections, routine maintenance and repair, and correct application of quality roofing products.

2. Definitions:

2.1. Low-Slope Roof. A low-slope roof has a slope (pitch) less than 250 millimeters per meter (3 inches per foot).

2.2. Pitch Roof. A pitch roof has a slope of 250 or more millimeters per meter. These roofs use composition shingles, or metal, clay, or concrete tiles. The user monitors these roofs, and roof maintenance personnel respond to complaints according to the warranty.

2.3. Slope Conversion. Converting low-slope roofs to pitched roofs (where feasible) can lengthen roof life and reduce maintenance and repair costs. The Air Force requirement for converting low-slope roofs to pitched (water-shedding) roofs is provided as attachment 2. This provides detailed

guidance and a standardized methodology for slope conversion, and requires economic analysis based on life cycle cost calculations following the procedures in the Oak Ridge National Laboratory Technical Manual No. 6520, *Decision Guide for Roof Slope Selection* (available from AFCESA/ENC).

3. Responsibilities:

3.1. Air Force Civil Engineer Support Agency (AFCESA):

- Establishes standards and policies for design, maintenance, repair, and management of roofing systems.
- Develops Air Force guide specifications for various roofing systems.
- Evaluates installation roofing and performs other professional engineering services.
- Establishes economic analysis technical guidance for roof conversions.

3.2. MAJCOMs:

- Manage roofing programs within the command.
- Appoint a roof engineer to monitor command roofing programs.

3.3. Base Civil Engineer:

3.3.1. Operations Flight:

- Schedules personnel to attend roofing courses.
- Monitors roof inspections, maintenance and repair work covered by performance agreements, and warranties for compliance.
- Ensures all contracted work becomes a part of the facility file.
- Decides whether roof repair work and maintenance will be done under contract or in-house.

3.3.1.1. Roof Engineers:

- Manage the base roofing program.
- Monitor contract work.
- Develop and maintain low-slope roof lists by generic type.
- Color code the roof lists with the Base Comprehensive Plan Drawing (refer to section C).
- Keep a list of roofs, by priority, that need replacing.
- Determine the most technically feasible and economical repair alternatives (recover, slope conversion, or replacement).

3.3.1.2. Roof Technicians:

- Develop and maintain the roof database.
- Administer the roof inspection program.
- Manage in-house maintenance and repair work.
- Order needed repair tools and equipment, and maintain equipment in the inventory.

3.3.2. Engineering Flight:

- Prepares plans, specifications and cost estimates for all contracted roof maintenance, repair, or replacement.
- Briefs the base facilities board on all roof maintenance, repair, and replacement requirements; and ensures work is properly programmed and priorities established.
- Inspects all contracted work.
- Retains a copy of all performance agreements and warranties.

3.3.3. Environmental Flight:

- Advises on proper disposal of roofing materials.
- Recommends sampling and analysis techniques to detect hazardous materials.
- Coordinates with the testing agent and provides the testing requirements to detect hazardous materials in the existing roofing system. Testing includes the roof system and attic space.

4. References and Training. Attachment 1 contains a list of publications to help the Base Civil Engineer select, plan, inspect, and maintain various roofing systems. It also contains a list of seminars/courses which are available for training roofing personnel.

5. Guidelines for Using the Roofing Industry Educational Institute, *Maintenance Membrane Roofing Systems*, Manual:

5.1. Compliance Requirements. Supervisors and roof maintenance personnel should use the Roofing Industry Educational Institute, *Maintenance Membrane Roofing Systems*, manual to the fullest extent possible, consistent with local operating conditions and capabilities.

5.2. Obtaining Copies. Organizations may purchase copies of this manual directly from the publisher: Roofing Industry Educational Institute, 14 Iverness Drive East, Building H, Suite 110, Englewood CO 80112-5608, (303)790-7200.

5.3. Reproducing Copies. HQ AFCEA has permission to reproduce the maintenance inspection checklist for military purposes only. Get written permission from the publisher before reproducing any other part of the manual.

Section B—Database Management

6. Organizing the Database. The roof engineer makes a facility list of all base low-slope roofs, then divides the list into three condition categories: red; yellow; and green. Explanation of these categories follows in paragraph 9.

7. Developing the Database. Develop the database as a byproduct of scheduled roof maintenance inspections. Maintenance of the database is an in-house responsibility.

7.1. Facility List. For each building on the facility list, include the facility number, user, the building's purpose, real property condition code, and name and telephone number of building custodian. For each roof area, record the age, roof category (red, yellow, green [paragraphs 9.1 through 9.3]), generic roof type, area, and slope.

7.2. Inspection Checklist. Address and record all areas of the Roofing Industry Educational Institute, *Maintenance Membrane Roofing Systems*, manual sample maintenance inspection checklist during inspections. Other similar checklists also are acceptable.

7.3. Historical File. Keep information such as the roof plan, inspection reports, maintenance and repair history, and the original warranty in the facility file. Use of a separate folder is optional. A special tab in the facility file should be designated for roofing information. This information may be stored in the Work Information Management System computer (if available), instead of a file folder.

7.4. Roof Plan. Make a small scale drawing for each roof showing actual roof conditions and measurements. Make a single-line drawing on regular letter-size (216- by 280-millimeter [8-1/2 by 11 inches]) stock showing a plan view of all roof areas on the building. A scaled aerial photo (203 by 254 millimeters [8 x 10 inches]) is also acceptable. For family housing, one roof plan can represent all houses of the same type.

7.4.1. Figure 1 is a list of common roof drawing symbols. You may use other symbols, but be consistent. For each drawing show:

- Roof dimensions (to the nearest half-meter) based only on field measurements.
- North.
- Area of each roof in square meters.
- Height of each roof area above the ground in meters.
- All penetrations, equipment, and features such as sanitary vent pipes, antennas, lights, ventilators, air conditioners, drains, expansion joints and scuppers.
- Slope, in millimeters per meter, and an arrow showing direction of downward slope.

7.4.2. Assign a number or letter designating each roof area on the roof plan. Use the following criteria to decide on limits for the areas.

- Show natural building divisions. These are upper and lower roofs, areas divided by expansion joints, separate wings of a building, and areas divided by firewalls.
- Each designated roof area must be the same age throughout.

8. Nondestructive Inspections:

8.1. Purpose. An aerial infrared survey of the base is an excellent aid to begin organizing a roof management program. Combined with a rooftop visual inspection and destructive verification of aerial findings, these surveys:

- Confirm leak tightness of newly constructed roofs (yellow category).
- Pinpoint leak sources and the extent of wet insulation to allow spot repairs or partial replacement.
- Confirm total number of roofs needing to be replaced.
- Establish a database reference for the roof management program.

8.2. Methods. The three methods of nondestructive inspections available are infrared, nuclear, and capacitance. These methods can supplement but never replace a visual maintenance inspection. Confirm an anomaly identified by nondestructive methods by taking a roof core sample and testing it.

Section C—Guidelines for Classification, Treatment, and Inspection

9. Establishing Categories. Classify each roof on the base as red, yellow, or green. The roof of a building with several modules or wings may have distinct areas falling into more than one category. The roof on one module or wing may be much older than others and require repair or replacement. However, an area can be classified in one category only.

9.1. Red. Classify a roof in the red category if one or more of the following conditions exist:

- Annual maintenance and repair costs consistently exceed 5 percent of the roof replacement cost.
- Leaks persist despite maintenance and repair efforts.
- Moisture or other elements have weakened the roof system or supporting structure making it unsafe.
- Insulation has lost at least 20 percent of original insulating ability due to moisture in the insulation core. Take a core sample and send it to a laboratory to confirm the condition.

NOTE:

Thermal resistance of some closed cell insulation decreases with time due to aging.

9.2. Yellow. Yellow category roofs are under warranty, performance agreement, or some other contractual tie to a contractor or manufacturer.

9.3. Green. Green category roofs are all other serviceable roofs which the Base Civil Engineer must maintain.

10. Treatment Alternatives. Consider life cycle costs when deciding among treatment alternatives, listed below.

10.1. Red Category. For low-slope roofing systems, you may:

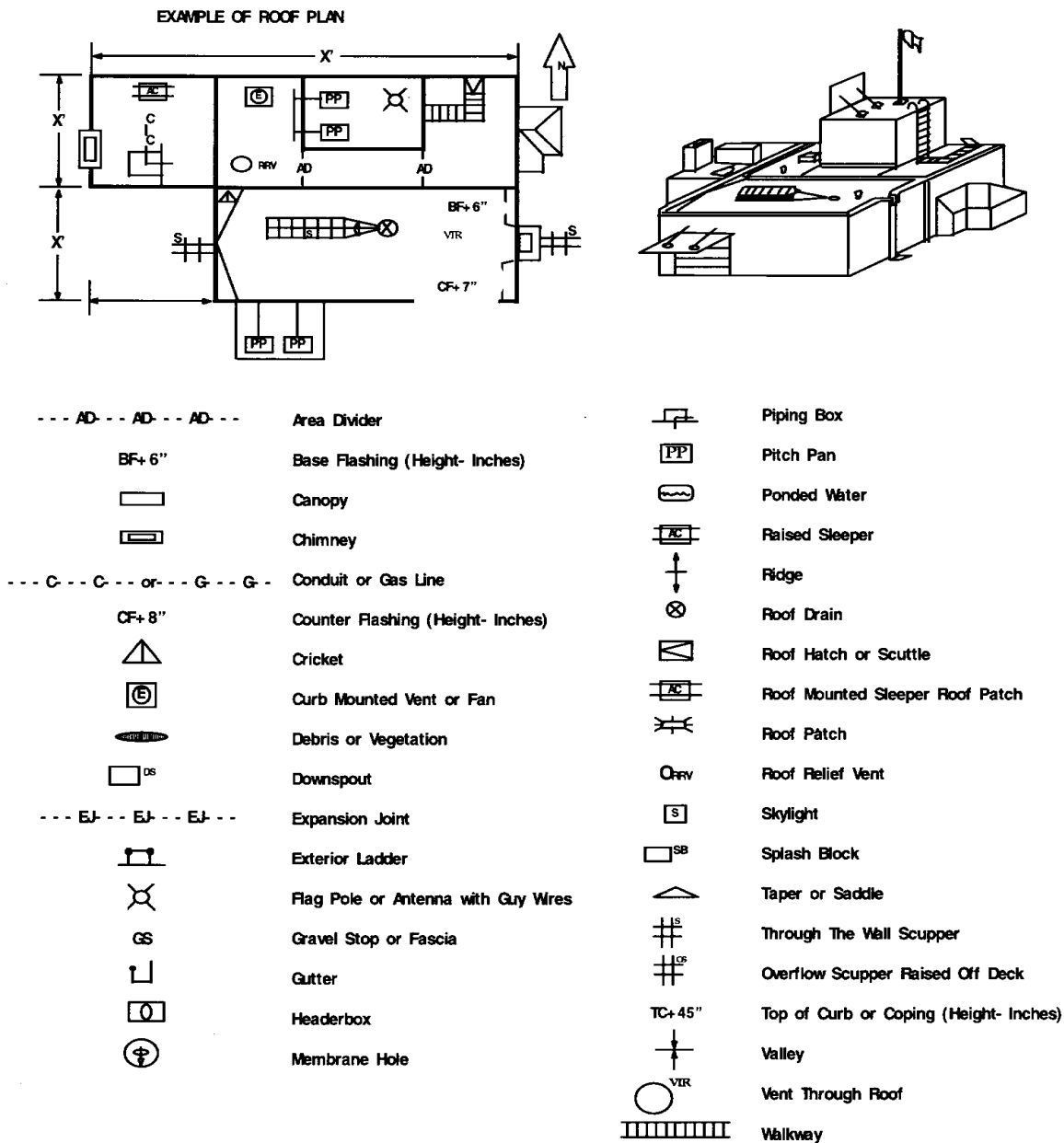
- Make hot and cold repairs, or partially replace the roof matching existing materials.
- Remove the old system and replace it with a new roof system.
- Install structural standing seam metal roofing, composition shingles, metal, clay, or concrete tiles for slope conversion projects.

10.2. Yellow Category. If a yellow category roof leaks, consider:

- Notifying the contracting officer.
- Reporting any defects to the contracting officer for review and further action.
- Performing a nondestructive evaluation of the roof system. Report any indications of moisture penetration and probable damage to the contracting officer. See paragraph 13.2 for emergency repairs.

10.3. Green Category. Refer to section D for guidelines for maintenance and repair of green category roofs. Schedule replacement of these roofs based on projected design life.

Figure 1. Roofing Symbols.



11. Inspection Procedures:

11.1. Red Category. Perform safety inspections on low-slope red category roofs at least annually. Check drainage systems and remove all debris from roofs to prevent excessive ponding of water and possible roof collapse. A detailed inspection usually is not necessary, since these roofs are on the repair or replacement list.

11.2. Yellow Category. Perform inspections on all yellow category roofs according to the warranty, guarantee, or performance agreement, but not less than once annually. As a minimum, check the

flashings, embedded metal, and ply laps in one-ply membranes. The warranty should cover most leaks and defects in the membrane and flashing systems.

11.3. Green Category. Perform a detailed inspection of all low-slope green category roofs in early spring using the Roofing Industry Educational Institute Maintenance Inspection Checklist. To help make the inspection safer and more complete:

- Conduct the inspection with at least two people. Inspecting roofs can be dangerous.
- Be alert when walking on a roof. Never step back without looking first.
- Group areas according to age. Record new areas on the roof plan.
- Don't step on blisters or edge flashings, or kick base flashings, or otherwise damage the roof.
- Mark the type, location, and extent of distress on the roof with spray paint. Mark the roof plan with a pencil.
- Order a nondestructive test of the roof if visual indications suggest moisture has penetrated the roof system.
- Refer to the Roofing Industry Educational Institute, *Maintenance Membrane Roofing Systems*, manual for definitions of typical roof construction and defects to designate a roof area.
- Plot each deficiency on the roof plan and submit AF Form 332, **BCE Work Request**. (See figure 1 for roofing symbols.)
- Conduct a followup inspection in late fall on all low-slope green category roofs. Discuss previously corrected problem areas with building managers to determine if roofs function satisfactorily. Check the drainage system for debris. Followup inspections may not be necessary or practical in locations with short summers, such as Alaska.

Section D—In-House Roof Maintenance

12. Roof Maintenance:

12.1. Repair Methods. Refer to repair methods in AFM 91-31, *Maintenance and Repair of Roofs*, the Roofing Industry Educational Institute, *Maintenance Membrane Roofing Systems*, and the following paragraphs.

12.1.1. Built-Up Roof and Modified Bitumen. Use the hot or cold method, depending on the type of job, personnel qualifications, and availability of materials and equipment. If resources are available to support both methods, use the most economical. Hot repairs usually are more economical when repairing an area 9.3 square meters (100 square feet) or larger.

12.1.1.1. The built-up roof hot repair method uses heated bitumen, felts, and aggregate to repair defective areas with material similar to the original roof. The current Engineering Technical Letter (ETL), *Built-Up Roof Repair/Replacement Guide Specification*, gives complete instructions for making hot repairs.

12.1.1.2. The built-up roof cold repair method uses mastic, felts, and fabrics. The Roofing Industry Educational Institute, *Maintenance Membrane Roofing Systems*, manual has instructions for making cold repairs.

12.1.1.3. In the modified bitumen hot repair method, repair material is either soaked in heated bitumen or torched down. The cold repair method uses a self-adhesive capsheet.

12.1.2. Other Systems. See the Roofing Industry Educational Institute *Maintenance Membrane Roofing Systems* manual for instructions on repairing other roof systems. Refer also to the Construction Engineering Research Laboratory publication, *Handbook for Repair of Non-Conventional Roofing Systems* (attachment 1), AFM 91-31, and the membrane manufacturer for repair information.

13. Emergency Repairs:

13.1. Red Category. Repair only when necessary to stop leaks.

13.2. Yellow Category. If a yellow category roof fails, promptly request guidance from your contracting officer. Make only those emergency repairs to prevent water damage to the interior until the manufacturer or contractor responds. Check the response time in the performance agreement or warranty.

13.3. Green Category. Make prompt emergency repairs to prevent water damage to building contents. Make permanent repairs as soon as possible.

Section E—Roof Design, Specifications, and Drawings

14. Contract Preparer Qualifications. Personnel preparing roofing contracts need current knowledge of roofing technology. See attachment 1 for additional reference materials with specific information about roof applications and replacements, and guidelines for preparing project documents. Consult your MAJCOM roof engineer for further help.

15. Preparing the Roof Contract Document:

15.1. Investigating the Roof Site:

15.1.1. Determine the existing roof condition. Cut at least one probe into each area of the roof system, making sure the probe extends down through all components to the structural deck. Repair the cuts immediately. Follow the repair procedures outlined in the current ETL, *Built-Up Roof Repair/Replacement Guide Specification*.

15.1.2. Use photographs to identify existing conditions on contract drawings. Indicate the roof's exact location on the photograph and its orientation on the roof plan.

15.1.3. Measure the location and size of all roof penetrations and equipment.

15.1.4. Plot areas of ponded water and note the cause to determine drainage requirements.

15.1.5. Use an arrow to indicate the downward roof slope direction. Determine the slope ratio and show it on the plan, in millimeters per meter.

15.1.6. Indicate the true north direction.

15.1.7. Make sketches of all detail conditions such as penetrations, curbs, and roof edges. Indicate the dimension of each detailed component. Include material type, fasteners, and similar information. Indicate whether the materials can be reused. Label each detail with a letter or number. Plot the detail's location on the roof plan (actual construction details usually do not appear on record drawings).

15.1.8. Where existing detail conditions appear inadequate, sketch possible alternative treatments next to the detail showing the existing conditions. Use standard construction details as a reference.

15.1.9. Where the detail is not apparent, probe as necessary to determine the underlying conditions.

15.1.10. Identify unused equipment and roof penetrations. Check with the building user before including removal of any equipment in the contract.

15.1.11. Note any problems such as insufficient clearance for roofing work between the roof and the bottom of equipment. Also, note deteriorations not directly related to roofing, such as metal work that needs painting.

15.2. Preparing the Specification. Consult your MAJCOM roof engineer for guidance on new built-up roof construction. Refer to the:

- Current ETL, *Built-Up Roof Repair/Replacement Guide Specification*, for major built-up roof repair and reroof work.
- Current ETL, *Guide Specifications - Ethylene Propylene Diene Monomer Roofing*, for single-ply systems.
- Corps of Engineers Guide Specification or US Navy Federal Guide Specification for other major roofing work. Attachment 1 provides mailing addresses.

15.3. Determining Construction Details. Refer to publications from the National Roofing Contractors Association and Sheet Metal and Air Conditioning Contractors National Association, Inc. for standard construction details. Refer to attachment 1 for addresses.

15.4. Developing Roof Project Drawings. Each set of drawings for a roofing project must contain (as applicable):

- A cover sheet with a map of the base that identifies all buildings covered by the contract. Also identify the Base Civil Engineer's office, contracting office, disposal areas, fire department, hospital, travel routes, and staging areas.
- A plan view of each building showing:
 - As-built dimensions.
 - Roof slope (in millimeters per meter), with arrows showing downslope, for each level (indicate dead levels and omit arrows).
 - Areas on the same building that have different types of bitumen or different roofing systems.
 - Areas of the deck most likely to need repair or treatment.
 - Replacement of deteriorated soffit and fascia areas.
 - Equipment (indicate which items to remove).
 - Roof access locations.
- The aboveground elevation for all roof levels. The contractor needs to know the height of the roofs for estimating and equipment planning.
- Section details for each area needing flashing. Every type of roof edge, end condition and penetration must have a section detail associated with it. Include a key showing where each

section detail applies on the plan view of the roof. If field conditions change, show clearly the materials to retain. Show these materials as "materials to be reused."

15.4.1. Details of Existing Conditions. Don't use a typical National Roofing Contractors Association or Sheet Metal and Air Conditioning National Association, Inc., construction detail unless it is compatible with existing conditions. Record existing conditions on the detail.

15.4.1.1. Measure to determine that maximum and minimum dimensions fit. Modify standard drawing dimensions, if necessary. Indicate:

- Existing wall construction.
- Existing deck construction.
- Existing insulation thickness.
- Existing bitumen type.
- A vapor retarder or underlayment, when present.

15.4.1.2. Determine if the plumbing connection to the roof drains requires attention in the contract.

15.4.1.3. Identify any asbestos-containing materials which may require special precautions or removal procedures.

15.4.2. Using Standard Details. Modify standard National Roofing Contractors Association and Sheet Metal and Air Conditioning National Association, Inc., details to suit local needs. Ask your MAJCOM roof engineer for help.

Section F—Roof Contract Management Program

16. Purpose. The purpose of roof contract management is to ensure the Air Force receives quality contractor-installed roofs.

17. Contractor Quality Control Responsibilities. The contractor is responsible for quality control according to the specifications.

17.1. Built-Up Roof and Ethylene Propylene Diene Monomer Single-Ply Systems. Refer to the quality control guidelines in the current ETLs, *Built-Up Roofing Repair/Replacement Guide Specification*, and *Guide Specification for Ethylene Propylene Diene Monomer Roofing*. Use AF Form 1063, **Quality Control Record**, according to the ETL.

17.2. Other Systems. Use the guide specification in ETL 90-8 for all ethylene propylene diene monomer roofing systems. Do not change any of the technical or warranty requirements. For all other roofing systems, use the appropriate US Army or US Navy guide specification.

18. Air Force Inspector Responsibilities. The Air Force inspector's job is to monitor the contractor's quality control program. During the first few days, remain at the job for several hours each day to observe the contractor's quality control program. After the contractor achieves a satisfactory level of confidence, you can reduce the time.

18.1. Audit Procedures. For built-up roof and ethylene propylene diene monomer systems use the audit procedures in the latest ETLs. Check each work item against actual job conditions for contractor compliance. Compare findings with the completed AF Form 1063 for consistency.

18.2. Evaluate Roof Samples. For built-up roof systems, evaluate a sample of the completed membrane assembly according to the built-up roof ETL. Ensure the contractor corrects any variances found in the sample. After establishing a satisfactory level of confidence, take samples only when the inspector or quality control monitor feels it necessary.

19. Acceptance of Daily Work. Evaluate work each day. Accept or reject the work and advise the contractor immediately. Use commercial laboratory services (if necessary) to confirm job conditions. Do not allow the contractor to proceed with new work until they have corrected the rejected work and adjusted the construction.

20. Project Close-Out. The contract management office makes sure the contractor furnishes as-built roof summary sheets and applicable manufacturer warranties. Provide copies of these documents to the roof engineer to place in the facility file. **NOTE:** The contractor should present warranties prior to final acceptance. Authorization for final payment should be withheld pending receipt of these documents.

21. Forms Prescribed. AF Form 1063, **Quality Control Record.**

JAMES E. McCARTHY, Maj General, USAF
The Civil Engineer

Attachment 1

LIST OF REFERENCES

References

Air Force Instructions/Manuals/ETLs:

AFI 32-1023, *Design and Construction Standards and Execution of Facility Construction Projects*

AFM 85-3, *Paints and Protective Coatings*

AFM 88-3, Chapter 1, *Structural Design Criteria Loads*

Chapter 3, *Masonry Structural Design for Buildings*

Chapter 14, *Design Criteria for Facilities in Areas Subject to Typhoons and Hurricanes*

AFM 91-31, *Maintenance and Repair of Roofs*

ETL 90-1, *Built-Up Roof Repair/Replacement Guide Specification*

ETL 90-8, *Guide Specification for Ethylene Propylene Diene Monomer Roofing*

Industry Manuals/Pamphlets:

A Guide To Preparing Built-Up Roofing Specifications

Manual of Roof Maintenance and Roof Repair

Quality Control Guidelines for the Application of Built-Up Roof

Residential Asphalt Roofing Manual

All: Asphalt Roofing Manufacturing Association

6000 Executive Blvd., Suite 201

Rockville MD 20852-3803

(301) 231-9050

Architectural Sheet Metal Manual

Sheet Metal and Air Conditioning Contractors National Association, Inc.

PO Box 221230

Chantilly VA 22022-1230

(703) 803-2980

Sectional Properties of Corrugated Steel

American Iron and Steel Institute

1133 15th Street NW., #300

Washington DC 20005

(202) 452-7100

Steel Deck Design Manual

Steel Deck Institute

PO Box 9506

Canton OH 44711

Single-Ply Roofing, A Professional Guide to Specification Manual of Roof Inspection, Maintenance and Emergency Repair for Existing, Single-Ply Roofing Systems

Single-ply Roofing Institute

20 Walnut Street, Suite 208

Wellesley Hills MA 02181

(617) 237-7879

Aluminum Standards and Data

The Aluminum Association

900 19th Street NW., Suite 300

Washington DC 20006

(202) 862-5100

Maintenance Membrane Roofing Systems

The Roofing Industry Educational Institute

14 Inverness Drive East

Building H, Suite 110

Englewood CO 80112-5008

(303) 740-7200

Spray Polyurethane Foam for New and Remedial Roofing

Guide to Selection of Protective Coatings Over Spray Polyurethane Foam

All: Polyurethane Foam Contractors Division

1275 K Street NW., Suite 400

Washington DC 20005

(800) 523-6154

Decision Guide for Roof Slope Selection, Oct 1988, Technical Manual 6520

Oak Ridge National Laboratory

Oak Ridge TN 37831-2008

The National Roofing Contractors Association Roofing and Waterproofing Manual

Application Techniques for Glass Fiber Roofing Felts

Quality Control Guidelines for the Application of Built-Up Roofing

Catalog of Publications and Audio Visuals

Roofing Materials Guide

All: The National Roofing Contractors Association

O'Hare International Center

10255 Higgins Road, Suite 600

Rosemont IL 60018-5607

1-800-323-9545

Magazines and Newsletters:

Contractors Guide

Century Communications

6201 Howard Street

Niles IL 60714-3455

(708) 647-1200

Roofing Industry Educational Institute Newsletter

The Roofing Industry Educational Institute

14 Iverness Drive East

Building H, Suite 110

Englewood CO 80112-5008

(303) 740-7200

Professional Roofing

The National Roofing Contractor's Association

O' Hare Inter

10255 Higgins Road, Suite 600

Rosemont IL 60018-5607

1-800-323-9545

Architectural Specifier, The Magazine of Roofing, Glazing and Exterior Walls

Century Communications

6201 Howard Street

Niles IL 60714-3455

(708) 647-1200

Roofing Siding Insulation

Edgell Communications

7500 Old Blvd.

Cleveland OH 44130

(216) 243-8100

Western Roofing, Insulation, and Siding

546 Court Street

Reno NV 89501-9834

(702) 333-1080

Roofer

D&H Publications, Inc.

6719 Winkler Road, Suite 214

Fort Myers FL 33919-9852

(813) 489-2929

Metal Architectural

Metal Construction News

Both: Modern Trade Communications

7450 N. Skokie Blvd.

Skokie IL 60077

(708) 674-2200

Texts:

Manual of Built-Up Roof Systems (Second Edition), by C.W. Griffin, Jr., P.E., for The American Institute of Architects, McGraw-Hill, 330 West 42nd St, New York NY 10036

The Science and Technology of Traditional and Modern Roofing Systems, by H.O. Laaly, 2 volumes, Laaly Scientific Publishing, 9037 Mount Mar Drive, Los Angeles CA 90035-4235

Government Handbooks/Reports Specifications:

Handbook For Repairing Nonconventional Roofing Systems, USA-Construction Engineering Research Laboratory Technical Manual M-89/04, PO Box 4005-1305, Champaign IL 61820-5580, (800) 872-2375

Membrane and Flashing Condition Indexes for Built-Up Roofs, Volumes 1 and 2, USA-Construction Engineering Research Laboratory Technical Report M-87/13

Membrane and Flashing Condition Indexes for Single-Ply Membrane Roofs, Inspection and Distress Manual, USA-Construction Engineering Research Laboratory Technical Report FM-93/11

Preliminary Recommendations for Maintenance of Factory-Coated Metal Siding and Roofing, National Bureau of Standards Interim Report 85-3193, June 86

Users Guide for Polyurethane Foam Roofing, Report No. UG-0011, Naval Civil Engineering Laboratory

Venting of Built-Up Roofing Systems, by Wayne Tobiasson, Cold Region Research Engineering Laboratory Miscellaneous Paper-1498, April 1981

Can Wet Roof Insulation Be Dried Out?, by Wayne Tobiasson, Charles Korhonen, Barry Coutermarsh, and Alan Groatorex, Cold Region Research Engineering Laboratory Miscellaneous Paper-1509, 1983

Condensation Control in Low-Slope Roofs, by Wayne Tobiasson, Cold Region Research Engineering Laboratory Miscellaneous Paper-2039, September 1984

Vapor Drive Maps of the USA, by Wayne Tobiasson and Marcus Harrington, Cold Region Research Engineering Laboratory Miscellaneous Paper-2041

Vents and Vapor Retarders for Roofs, by Wayne Tobiasson, Cold Region Research Engineering Laboratory Miscellaneous Paper (no number assigned)

Corps of Engineers Guide Specification

US Navy Federal Guide Specification

US Army Construction Engineering Research Laboratory Sloped Roof Conversions For Small Flat Roof Buildings, Technical Report -85/05, Dec 84

NOTE: Above publications can be ordered from the National Technical Information Service, Springfield VA 22161.

Seminars/Courses:

Roofing Industry Educational Institute:

- Roofing Technology.
- Single Ply and Mod-Bit Roofing Systems.
- Roof Repair and Maintenance.
- Architecture and Standing Seam Metal Roofing Systems.
- Roof Inspection, Diagnosis, and Repair.
- Roofing and Asbestos.
- Reroofing and Retrofit.
- Quality Assurance.
- Preparing and Enforcing Roofing Specification.
- Steep Roofing Systems.
- Introduction to Roofing.
- Roof Inspection and Maintenance.
- Sprayed-in-place Polyurethane Foam.
- Roof Asset Management.

Air Force Institute of Technology:

- Roof Design and Management (ENG 440).
- Facility Systems Design (ENG 480).

Sheppard Technical Training Center:

- Roofing Repair (Built-Up) Course No. J3AZR55250-000.

Attachment 2

ROOF SLOPE CONVERSION REQUIREMENTS

A2.1. Conversions of roofs from flat to sloped can be classified as repair, provided an economic analysis based on life cycle cost engineering proves the cost effectiveness of the conversion as the best means to effect repairs. Approval authority will be according to figure 2.1 of AFR 86-1, volume I, *Programming Civil Engineer Resources--Appropriated Fund Resources*, and table 2 of AFR 86-1, volume II, *Programming Civil Engineer Resources--Nonappropriated Fund Resources*. A slope conversion project is a method of providing a steeper roof pitch and requires use of a structural system, such as trusses, posts, and beams.

A2.2. Engineering Technical Letter 90-1, *Built-Up Roof Replacement Guide Specification*, mandates the requirement for providing a minimum slope of 21 millimeters per meter (1/4 inch per foot) to prevent ponding in both new and reroofing projects. This minimum slope is a basic design parameter and must be followed. Construction of dead-flat roofs is a design mistake which must be corrected during reroofing operations. Minimum slope can be achieved without structural modifications by using tapered insulation and light-weight fill. Minor slope adjustment to prevent ponding water can be accomplished as repair without an economic analysis.

A2.3. The benefits and advantages of converting to watershedding roof systems, where feasible, have been addressed and actively promoted by the roofing industry. Longer roof lives and reduced maintenance and repair cost are two economic advantages. To further clarify requirements and establish an institutionalized approach for developing economic analysis studies for slope conversion projects, the following criteria and guidance are provided.

A2.4. General conditions for slope conversion:

- Roof needs replacement due to deteriorated condition.
- Roof must be readily convertible to pitch without resorting to interior gutters.
- No functional space is gained either inside or outside (footprint).
- Useful life of the facility exceeds life of roof system selected.
- Roof conversion is justified based on a life cycle cost economic analysis.

NOTE:

If the roof conversion is essentially for aesthetics, the work class is construction.

A2.5. Accomplish the life cycle cost basis economic analysis using the detailed procedures, life cycle cost worksheet and discounted cost factors from chapter 4 of Oak Ridge National Laboratory Technical Manual No. 6520, *Decision Guide for Roof Slope Selection*. Use this standardized methodology for developing the economic analysis as the basis for classifying conversion projects as repair; include and maintain the paperwork in the project folder. Two copies of Technical Manual No. 6520 were previously provided to all Base Civil Engineer organizations; however, if you need a copy, please contact HQ AFC-ESA/ENC at DSN 523-6236.

A2.5.1. Use the following factors in table A2.1 for selected systems in the life cycle cost computations.

Table A2.1. Life Cycle Cost Computations.

Roof Types	Built-Up Roof 4-Ply	Asphalt Shingles	Metal SSM	Clay, Slate, Concrete Tile	Single-Plies
Roof Life (Yrs)	12-20(1)	15-25(1)	25	40+	5-15(3)
Maintenance Cost (\$/SF)	0.03	0.01	0.01		0.005(3)
Salvage Value (\$)	0	(2)	(2)	(2)	(2)
Initial Cost/SF	(4)	(4)	(4)	(4)	(4)
Discount Rate 10%	(5)	(5)	(5)	(5)	(5)
Energy Cost (\$)	(6)	(6)	(6)	(6)	(6)

NOTES:

1. Justify using factors other than those shown. Select within range shown based on local experience. Use 15 years for standard and 25 years for heavy duty (325 lb) shingles.
2. Salvage value = sloped structural system + deck + reusable insulation as appropriate.
3. Use manufacturer's published data for specific system used/or standard warranty period.
4. Use actual cost based on previous projects and/or nationally recognized cost estimating guides. Refer to paragraph A2.5.2.
5. Use factors from table 4-2, Oak Ridge National Laboratory Technical Report 6250, to annualize costs.
6. Compute based on the generic insulation selected. Reference Oak Ridge National Laboratory Technical Manual-9004.

A2.5.2. Prepare detailed cost estimates identifying all system components for the various roofing alternatives under consideration. As a minimum, prepare the cost breakout as shown in table A2.2 for each option.

Table A2.2. Cost Breakout.

Item	Scope	Unit	Cost		
			Labor	Material	Total
Membrane type		SF			
Insulation R-value		SF			
Vapor barrier		SF			
Base flashing/gravel stops		LF			
Penetrations/curbs		EA			
Expansion joints/area dividers		LF			
Drains		EA			
Piping		LF			
Gutters and downspouts		LF			
Slope conversion		SF			
Decking (type)		SF			
Structural					
System (type)					
Miscellaneous items		SF			
Skylights		EA			
Roof hatches					
Walkways					
GRAND TOTAL					

A2.5.3. In addition to the detailed cost estimates and life cycle cost worksheet, include a description of the existing facilities as follows:

- Current roofing system and deck type.
- Dimensions of facility (length/width/height).
- Date facility constructed and cost.
- Anticipated facility service life.
- Reasons for roof replacement.
- Proposed new roof system.